INDIVIDUAL CHARACTERISTICS AND ACHIEVEMENT OF PRE-SERVICE ELEMENTARY TEACHERS ON A COMPUTER LESSON ON DIAGNOSIS OF ERROR PATTERNS

By

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The purpose of this study was to identify specific patterns characteristic of subjects using a computer lesson designed to teach diagnosis of error patterns in addition and subtraction and to relate these characteristics to achievement on a posttest. The 43 subjects were prospective elementary teachers in the Childhood Education Program enrolled in Elementary Mathematics Methods at the University of Florida. From the results of a pilot study, conceptual tempo, as indicated by the Matching Familiar Figures Test, and the strategy used by the subject in determining error patterns became the focus of this investigation.

The computer lesson <u>Buggy</u> was used in this study as a method of teaching pre-service teachers to identify error

patterns. Each subject worked from one to two hours on the computer lesson. During that time the subjects were allowed to work on any or all six of the available error patterns. Each of the subject's interactions with the program was recorded, and the predominant strategies were classified. When the subject indicated that he or she was finished, a posttest was given. The posttest contained error patterns with which the subject had just finished working as well as error patterns which the subjects had not previously seen.

The data were analyzed using a regression equation. Achievement was the dependent variable, and strategy and efficiency (or conceptual tempo) were the independent variables. Following the elimination of the interaction term, the significance of each of the independent variables was tested. The strategy the subject used was not significant. The conceptual tempo of the subject was significant (.05 level). Using the Dunn Multiple Comparison Procedure, the reflective subjects scored significantly better than the impulsive subjects.

Directions for future research include: (1) Replicating this study with larger and/or different samples; (2) Searching for other individual characteristics which relate to achievement on a computer lesson; (3) Identifying computer lesson attributes; and (4) Relating individual characteristics with corresponding computer lesson attributes to effect maximum achievement.

CHAPTER I
INTRODUCTION

The rapid increase in computer availability and utilization has produced a critical responsibility for our nation's educational system, the requirement to expand computer literacy and use at all levels of our educational system. Computers have already become a valued tool to educational administrators in financial planning, attendance record keeping, grade reporting, and scheduling. With the advent of the personal computer at a relatively affordable price to the individual, the increased use of computers for instructional purposes in the classroom is now a distinct possibility. However, more research is necessary for the efficient implementation and use of the computer in the classroom. One facet of needed research is the extent to which individual differences affect the achievement of students using the computer to assist instruction.

In order to study the individual differences of students using the computer, a topic in mathematics education had to be found which was adaptable to this investigation. Due to the availability of a functioning

computer lesson on diagnosis and the probability that the subjects would be unfamiliar with error patterns, diagnosis became the ideal vehicle for this investigation. Diagnosis is the identification of error patterns in arithmetic computations. Through a computer lesson, the computer, by assuming the role of an errant child, can aid the pre-service teacher in learning to recognize patterns of incorrect computations. Thus, using diagnosis as the vehicle, this investigation inquired into the nature of individual differences and their effect on achievement of pre-service elementary teachers using the computer to diagnose error patterns in arithmetic computations

Statement of the Purpose

The purpose of this investigation was to identify specific patterns characteristic of subjects using Buggy, a computer lesson designed to teach diagnosis of error patterns in addition and subtraction, and to relate these characteristics to achievement on a posttest.

A series of questions led to the development of the hypotheses used in this investigation. In order to determine a manner in which the subjects could be compared or grouped, some method of determining achievement had to be developed. The most useful way of defining achievement was determined to be a posttest constructed to demonstrate the subjects' understanding of familiar and of new error patterns.

Question 1:

> While using the computer lesson Buggy, do the subjects exhibit certain behaviors or traits which can be used to predict achievement?

The examination of the computer lesson Buggy suggested other questions. Buggy was designed to emulate a child with error patterns in addition and subtraction computations. In order to determine a computer generated error pattern, the subject could ask for more examples, give test problems to be answered, and/or demonstrate his or her mastery of the error pattern by taking a quiz and completing computer generated problems using the same error pattern. In terms of Buggy, individual traits were defined according to which strategy the subject seem to prefer.

Question 2:

> Is there a difference in achievement among subjects who mainly request examples, subjects who mainly give the computer test problems, and subjects who mainly use quizzes to guess the error patterns?

Traits, however, could not be limited to specific, observable, physical behaviors. The subjects brought certain innate characteristics with them to the computer terminal. One trait considered was conceptual tempo, or reflectivity-impulsivity, as indicated by the Matching Familiar Figures Test. This trait is a subject's tendency to consistently respond slowly or quickly in a problem situation.

Question 3:

Is there a difference in achievement among subjects who are impulsive, reflective, or neither?

Hypotheses

The following sets of hypotheses were derived from the previously posed questions. Hypotheses I, II, and III dealt with the total posttest score as the independent variable.

Hypothesis I
There is no interaction between the strategy and conceptual tempo of a subject on the total posttest score.

Hypothesis II
There are no differences among those subjects classified as impulsive, reflective, or neither on the total posttest score.

Hypothesis III
There are no differences on the total posttest score among subjects who used different strategies in finding error patterns.

Hypotheses IV, V, and VI dealt with the portion of the posttest derived from error patterns with which the subject had worked on *Buggy*.

Hypothesis IV
There is no interaction between the strategy and conceptual tempo of a subject on the score of the portion of the posttest derived from error patterns with which the subjects had previously worked.

Hypothesis V
There are no differences among those subjects classified as impulsive, reflective, or neither on the score of the portion of the posttest derived from error patterns with which the subjects had previously worked.

Hypothesis VI
On the score of the portion of the posttest derived from error patterns with which the subjects had previously worked, there are no differences among subjects who used different strategies in finding error patterns.

Hypotheses VII, VIII, and IX dealt with the score of that portion of the posttest derived from error patterns with which the subjects had not previously worked on Buggy.

Hypothesis VII
There is no interaction between the strategy and conceptual tempo of a subject on the score of the portion of the posttest derived from error patterns with which the subjects had not previously worked.

Hypothesis VIII
There are no differences among those subjects classified as impulsive, reflective or neither on the score of the portion of the posttest derived from error patterns with which the subjects had not previously worked.

Hypothesis IX
On the portion of the posttest score derived from error patterns with which the subjects had not previously worked, there are no differences among subjects who used different strategies in finding error patterns.

Rationale

Even with the drop in cost of computers, the situation wherein each student has access to a terminal of his or her own is probably a long way in the future. The classroom teacher who has access to computer facilities will have to assign certain students to use the available computers and must learn to make the most efficient use of them in

instruction. An accurate knowledge of the distinctive qualities of the learner and of the relationship between these qualities and the use of the computer in the classroom is essential to such a teacher. If the teacher, knowing the individual characteristics of his or her students, could know in advance that a given student with certain characteristics would make more progress by instruction through the use of a computer lesson than a student without such characteristics, then the efficiency of computers in the classroom could be increased. This concept meets one of the most important aims of educational enterprises: "to create conditions that will facilitate the child's acquisition of knowledge" (Kagan, 1965a, p. 133).

Using the computer lesson Buggy is an example of facilitating the pre-service teacher's aquisition of knowledge concerning error patterns in basic computations. With the increased effort to raise the level of basic skills, a greater understanding of how and why elementary students make mistakes is important. Any method designed to teach diagnosis of error patterns is of interest and potential use to mathematics educators. As a computer lesson, Buggy not only serves this original purpose, but also serves to increase computer use and, consequently,

computer literacy. But, increasing the use of computers is not enough. The investment in computers is expensive enough to be prohibitive. Research must give direction for the effective use of computers in the classroom.

Subjects

The 43 subjects were prospective elementary teachers in the Childhood Education Program enrolled in Elementary Mathematics Methods at the University of Florida. These subjects were given credit for one of the activities required in their methods class. Of the 43 subjects who participated in the study, 40 sets of usable data were obtained. The mean age of the subjects was 23 with a range of 20 to 40. Most of the subjects had had no previous experience with a computer. Of the 40 subjects from whom computer data were obtained, 12 were classified as impulsive, 9 as reflective, and 19 were placed in a separate category labeled neither.

Procedures

A pilot study was conducted to identify potential traits which might predict achievement. From the results of the pilot study, conceptual tempo and the type of strategy used by the subject in determining error patterns became the focus of the present investigation.

Four to six weeks prior to the computer lesson, the 43 subjects were given the Matching Familiar Figures Test which indicated their conceptual tempo. Each subject worked from one to two hours on the computer lesson. During that time they were allowed to work on any or all of the six available error patterns. Each of their interactions with the program was recorded, and assignments to strategy were made. When the subject indicated that he or she was finished, a posttest was given. The posttest contained error patterns with which the subject had just finished working and error patterns which the subjects had not previously seen.

The data were analyzed using a regression equation in which achievement was the dependent variable. The independent variables were strategy and efficiency (or conceptual tempo). Following the elimination of the interaction term, the significance of each of the independent variables was tested and then checked with a one-way analysis of variance.

Definition of Terms

The following terms were used in this study:

Achievement: score determined from the posttest following the computer lesson. Also see tried and untried.

Buggy (Brown and Burton, 1977): a computer lesson based on the diagnostic interactions of a subject trying to determine an error pattern generated by the computer.

Computer Lesson: a combination of tutorial, drill and practice, and simulation.

Conceptual Tempo: the tendency of a subject to be reflective or impulsive in responding to a situation in which the solution is uncertain. Conceptual tempo is determined by the Matching Familiar Figures Test.

Diagnosis: identification of a consistent error pattern in arithmetic computation.

Efficiency (Young, 1973, p. 9): standardized continuous score obtained from the Matching Familiar Figures Test by multiplying a subject's total errors by 100 and adding this to their response time total.

Impulsive (fast-inaccurate): a subject who, on the Matching Familiar Figures Test, makes more errors than the sample median and whose mean latency to first response is less than the sample median.

Matching Familiar Figures Test (MFFT; Kagan et al., 1964): a test of 12 items in which the subject is asked to match a given picture with one of eight similar pictures and whose purpose is to determine conceptual tempo.

Reflective (slow-accurate): a subject who, on the Matching Familiar Figures Test, makes fewer errors than the sample median and whose mean latency to first response is larger than the sample median.

Strategy: the predominant method used by the subject in identifying error patterns in Buggy. These methods consisted of asking for examples, giving test problems, taking quizzes, or no dominate method.

Tried: achievement as a percentage score of that portion of the posttest derived from error patterns with which the subject had worked on the computer lesson Buggy.

Untried: achievement as a percentage score of that portion of the posttest derived from error patterns with which the subject had not previously worked.

Limitations

One, the subjects participating in this study were limited to 40 pre-service elementary teachers at one university during the winter quarter of 1980.

Two, the classification of adults by conceptual tempo was accomplished using the Matching Familiar Figures Test. This study accepted the validity of that test.

Three, the implications of how or whether Buggy "teaches" diagnosis of error patterns in addition and subtraction computations were not questioned.

Organization of the Study

The remaining chapters are organized in the following fashion. Chapter II contains the background of the problem, the state of the art in instructional computing, the review of the related research in instructional computing, a discussion of conceptual tempo, diagnosis as a subject for a computer lesson, a description of Buggy, and a synthesis of the related literature. Chapter III contains a pilot study, alterations to the computer lesson Buggy, a description of the subjects, the data collection and the procedures followed in the investigation. Chapter IV contains the analysis and interpretation of the data. Chapter V contains the directions for future research.

CHAPTER II
REVIEW OF THE RELATED LITERATURE

The purpose of the review of related literature is to provide an overview of the theories supporting this study and to highlight the research of the different areas combined in this study. Three distinct topics are covered: computer science in education, conceptual tempo, and diagnosis of error patterns in basic computations. In each case, the theories concerning each area are presented first, followed by the research relative to that area and this investigation. This chapter is organized according to the following topics: the background of the problem; the state of the art of instructional computing; the review of the related research in instructional computing; conceptual tempo; diagnosis as a subject for a computer lesson; background information on the computer lesson Buggy; and a synthesis of the related literature.

Background of the Problem

The theory behind this investigation dealt primarily with the effect of individual differences among students in a similar learning environment. Such ideas have dated back to the turn of the century. In 1911 Thorndike spoke

of the deadening effects of uniformity on students. Since that time, this theme has continued to be researched. The problem as understood by Glasser (1972) has been the adjustment of our educational system to an adaptive environment capable of meeting individual needs.

The theory of individual differences is emphasized in modern society by the identification of individual educational goals and by the realization that different methods may be used to obtain the same goals. Given that a single maximally effective strategy does not exist, Kilpatrick stated that the most logical approach to reaching a desired educational goal "would be the identification of individual difference variables" (1975, p. 69). With the knowledge of such variables a student could be matched to the most effective strategy. This investigation sought to isolate and identify individual difference variables associated with the use of a computer lesson and their effects on achievement.

State of the Art in Instructional Computing

Computer technology is a recent development evolving at an exponential rate. The microcomputer is even more recent as are its applications in education. To try to gain an understanding of where that technology is currently

poised can be compared to analyzing highway use by looking at one still photograph. To stop the action is to lose the essence of what is occurring.

Computer technology has witnessed revolutionary breakthroughs in speed and size. Small microcomputers now have the capability of executing hundreds of thousands of programmed instructions per second. Long, time consuming tasks, such as locating and updating personnel files or making statistical computations for research studies, can be done in nanoseconds. Computers of equal power which use to fill entire rooms now have been reduced to the size of typewriters.

Given the speed with which these changes have occurred, the effect on educational research is difficult to perceive. The uses to which computers can be put in the instructional setting are only slowly being realized and accepted. In one way, the situation is similar to that of the calculator. Electronic calculators have become invaluable in the last ten years, but educators still debate their usefulness in the classroom. With the exponential growth of computer technology, educational research consequently lags behind. In the field of instructional computing, that which is being researched now may already be obsolete.

As a result of this phenomenon, many educators feel that computer literacy will prove to be the next crisis in education (Molnar, 1978). In order to compete and even interact in the society of the future, individuals will need to have the knowledge of quick and easy access to vast amounts of information. Computer literacy, beginning in the schools, is the key to that knowledge.

Computer science may well gain its strongest and most accepted foothold in the classroom as a subject for study just as other subjects have filtered down from the college or university curriculum. Slowly, a limited number of computers may then become available to other subject areas of the curriculum for instructional purposes. Some foresighted educators have already made a limited number of computers available for instructional purposes.

The application of these computers and the related instructional computing is usually a form of computer assisted instruction (CAI). The emphasis in CAI should be placed on the word instruction. As stated by Sanders, "CAI refers to a learning situation in which the student interacts with and is guided by a computer through a course of study aimed at achieving certain instructional goals" (1977, p. 340).

In this type of activity, the student sits at a computer and communicates with a program. The computer and program are substituted for the teacher and textbook as the methods of instruction. The computer gives instructions and information; then through questions, the computer interacts with the student to determine if the student is ready to proceed.

CAI applications can be divided into several kinds of functions though they are often mixed together in a given lesson. Drill and practice CAI is probably the most used form. Previously learned facts are asked of the student and quickly judged by the computer. This approach is used to improve memory and accuracy of facts, such as the basic multiplication facts.

Tutorial CAI differs from drill and practice in that it presents new material to the student much as a textbook does. But, tutorial CAI also provides opportunities for interaction with the student such as a tutor might provide. This interaction is attained through branching in the program to account for any possible response a student might give. Sanders describes it in the following manner: "Students may follow any one of a number of anticipated paths in the program to a terminal point, but each of these paths has been programmed, and the overall sequence of presentation of

material is fixed" (1977, p. 342). Tutorial CAI lessons are generally structured and appear broad in the number and kind of responses they will accept.

The CAI functions can be extended through simulation or modeling. These activities demonstrate the structure of a real system or one proposed by the student and allow different stimuli to be administered to illustrate the effect of the variation. An example would be a simulation of a moon landing in which the student is allowed to vary the speed of the landing craft.

Review of the Related Literature in Instructional Computing

The majority of the educational research on computer assisted instruction compares CAI to traditional, established instructional methods. Edwards, Norton, Taylor, Weiss, and Van Dusseldorp in a 1975 review of CAI studies found that results were mixed when CAI was substituted for traditional methods. The reviewers list the studies of Wilson and Fitzgibbon (1970), Cole (1971), Adams (1969), Morgan and Richardson (1972), and Lorber (1970) as attaining positive results for CAI. However, an equal number of studies, including Morrison and Adams (1968), Cropley and Gross (1973), Proctor (1968), Johnson (1966), and Culp (1971), found no significant differences.

When reviewers looked at studies which used CAI as an enrichment of already existing instructional methods, the results were far more favorable for CAI methods. All of the studies listed, Suppes and Morningstar (1972), Arnold (1970), and Fletcher and Atkinson (1972), found that students gained when normal instruction was supplemented with CAI.

More recent studies agree. Daellenback, Schoenberger, and Wehrs (1977) conducted a study which is typical in that it compared the effect of CAI on cognitive and affective development of college students. CAI, in which students had the opportunity to complete fourteen tutorial lessons, five games, and one simulation, was substituted for the traditional lecture, textbook approach. The CAI materials had a positive effect on basic analytic ability, but the materials were not significant across all types of cognitive behavior.

Another study of this nature was done by Tsai and Pohl (1977) in a college level programming course. Four types of performance evaluation techniques, including quizzes, homework assignments, term projects, and final examinations, were used to compare lecture, computer-aided instruction,

and lecture supplemented with computer-aided instruction. Significant differences were detected between the groups on the quizzes and final examination.

These studies appear to imply that if the CAI methods do not compare favorably with traditional methods, the computer in the classroom should be abandoned. In each of the studies mentioned, the computer was used as the alternative for a whole class. The computer's usefulness may be far more important on an individual level.

Some educational studies address individual differences among students using the computer as an instructional strategy indirectly. Edwards et al. (1975) in their review listed two studies, Martin (1973) and Suppes and Morningstar (1972), which reported results according to ability grouping. These studies "found CAI drill and practice in arithmetic to be relatively more effective for low ability students than for average or high ability students" (Edwards et al., 1975, p. 151).

More recent studies have also mentioned similar results. Lysiak, Wallace, and Evans (1976) in their evaluation of a CAI program in the Fort Worth, Texas, school system found that low ability students achieved significantly better than high ability students. Ability was defined from performance on a pretest. These studies suggest that there may be other attributes which identify students who may perform significantly better through CAI methods.

The most complete and direct study of individual differences and the use of CAI done to date is that of Federico and Landis (1980) for the U. S. Navy. That study used 166 Basic Electricity & Electronics Preparatory School students as subjects to search for relationships among cognitive style, abilities, and aptitudes and found cognitive style to be relatively independent of abilities and aptitudes. Aptitude was defined as knowledge of content areas. The "independence" means that all three topics must be explored to predict achievement. More significantly the conclusion stated that it seems likely that students may learn more readily and retain knowledge more easily by designing different instructional strategies which take into account the differences among students.

The review of the literature on individual differences among students using CAI reflects critical implications. The majority of the research compares CAI to traditional, established instructional methods. The studies that have been done are only at the threshold of discovery. The present study, therefore, sought to explore individual differences of pre-service teachers using a computer lesson.

Conceptual Tempo

In searching for aptitudes which might affect student performance on Buggy, the pilot study and several additional requirements had to be considered and weighed. The pilot study indicated that the subjects seemed to be concerned with time and being right, and the aptitude had to be one which was well established, documented and researched in order that the emphasis of the study could be placed on the relationship of the aptitude and the computer module and not on the existence and validity of the aptitude. The aptitude needed to be bipolar to limit the possible categories into which the number of subjects might fall. And finally, the instrument used to test for the presence of the aptitude needed to be relatively easy and quick to administer to allow feasibility of a classroom teacher's use. These considerations lead to the use of conceptual tempo.

The development of conceptual tempo is associated with Kagan and is usually measured by the Matching Familiar Figures Test (MFFT). Kagan (1965a) defines this variable of decision time, which is sometimes referred to as reflectivity-impulsivity, as "the child's consistent tendency to display slow or fast response time in problem situations with high response uncertainty" (p. 134).

Reflective students are more persistent and set greater goals on intellectual tasks in their early school experiences. The reflective child works for longer periods of time and tends to avoid peer group interaction. Kagan observed that a reflective child would often stand on the "sidelines" and intently study the group before becoming a part of it. More often than not, the reflective child avoids those activities and becomes involved in quiet, solitary activities. The impulsive student tends to enter into group interaction "with zeal and appears to enjoy active social participation" (Kagan, 1965a, p. 156).

Kagan suggests that conceptual tempo is visible in the conflict between two consistent demands made of students. Teachers reward students who return results as quickly as possible, but they also reward students for not making mistakes. Often a child must choose between the two paths to receive a reward. This conflict typifies the impulsive child who places more emphasis on quick success rather than on avoiding failure, as opposed to the reflective child who is afraid of situations that may lead to failure and is willing to wait for success.

Most of the research on conceptual tempo has been done with children. Kagan and Kogan (1970) in Carmichael's Manual of Child Psychology suggest and support the following findings.

The tendency to be reflective or impulsive in young children is stable over short periods of time as measured on the MFFT (Messer, 1970). There is some generalization of impulsivity-reflectivity over different tasks (Kagan, 1965b). The tendency toward impulsivity is "somewhat modifiable." A study by Nelson (1968) found that a training regimen that emphasizes accuracy only and ignores speed of response produces both longer response times and fewer errors in impulsive children. In fact, American children become more "cautious" as they mature and thus become more reflective with age (Draguns and Multari, 1961; Westcott, 1968).

While there have been few studies carried out with adults, several stand out. Yando and Kagan (1968) looked at the effect of teacher tempo on the student. Their results indicated that reflective teachers influenced first-grade children to become more reflective than did impulsive teachers. Young (1973) tried to relate the conceptual tempo of adult subjects to academic motivation, habituation of the orienting response, short-term memory, and introversion-extraversion. However, multiple correlations were not significant possibly because the

subjects tended toward reflectivity and did not represent the entire spectrum. Federico and Landis (1980) in their study with Navy personnel found that conceptual tempo contributed to the problem solving mode and was independent of ability and knowledge of content areas.

Diagnosis as a Subject for a Computer Lesson

The decision to use diagnosis of error patterns as a CAI topic in this investigation was based on several factors. While diagnosis is a recognized area of interest and research in mathematics education, little is known of the topic in other fields. This fact helped to insure that the subjects in the present study had had little or no contact with diagnosis before completing the computer lesson.

Recently, mathematics educational goals have been focused on the redevelopment of elementary mathematical concepts in compensatory education programs. This impetus, from the "back to basics" movement, has resulted in renewed interest in diagnosis of error patterns in elementary mathematics education programs. These two factors coupled with the availability of appropriate subjects and the accessibility of the functioning program Buggy made diagnosis the ideal topic for the computer lesson used in this investigation.

The theory behind diagnosis is best described by Piaget (1964) who defined knowledge as an interaction which could be observed. The importance of knowledge was not the product but the process needed to gain that product. If the process could be observed and understood, then knowledge could be understood. Diagnosis is the understanding of the process by which a child performs an algorithm. Once that process is understood, faulty algorithms can be diagnosed, and prescriptions can be made for corrections of the faulty error pattern.

This process can best be understood by considering the diagnosis of what is wrong with the algorithm employed by the following student. Several examples of a student's work are examined as might be done by a teacher grading homework.

Sample of the student's work:

$$\begin{array}{r} 6 \\ +3 \\ \hline 9 \end{array} \quad \begin{array}{r} 7 \\ +5 \\ \hline 12 \end{array} \quad \begin{array}{r} 67 \\ +18 \\ \hline 715 \end{array} \quad \begin{array}{r} 35 \\ +92 \\ \hline 127 \end{array} \quad \begin{array}{r} 56 \\ +97 \\ \hline 1413 \end{array} \quad \begin{array}{r} 74 \\ +56 \\ \hline 1210 \end{array}$$

The student is obviously doing something wrong. While the basic addition facts appear to be known, the student is incorrectly regrouping for place value.

The importance is in how the teacher approaches the problem. Believing that the errors are random, the teacher could reteach the entire unit on regrouping to this

individual student. However, on closer examination of the problems, the teacher might realize that in each case the student followed a very systematic pattern. First the ones were added and regrouped, then the tens were added and regrouped, both without regard to place value. Therefore, instead of reteaching the entire unit, the teacher might prescribe some activities which would remediate this specific problem.

Teachers many times assume that students follow erratic behavior patterns in using algorithms. Research in this area has shown that students are competent procedure followers. Roberts (1968) in his study of failure strategies of third grade arithmetic pupils identified four error categories: wrong operation, obvious computational error, defective algorithm, and random response. The greatest number of incorrect problems was because of defective algorithms. Cox (1975) found that these failure strategies persisted for long periods of time without instructional corrections. Englehart (1977) replicated Robert's study with similar results. Extension of a similar classification method by Radatz (1979) classified errors according to language difficulty, deficient mastery of prerequisites, incorrect skills, facts, or concepts, and application of irrelevant rules of strategy.

Once conceptual error patterns have been separated from careless mistakes, West (1971) indicated that the most effective and efficient procedure for diagnosis was to identify the precise nature of the problem, and then prescribe to remediate the problem. Possibly the most definitive work to date is the semi-programmed approach by Robert Ashlock (1976). This book aids the pre-service teacher in diagnosing many of the major computational error patterns in arithmetic and prescribing corrective procedures. The CAI program Buggy is modeled in a similar fashion to Ashlock's diagnosis procedure.

Buggy, A Computer Lesson for Training Pre-service Teachers

Buggy was developed by Brown and Burton (1977) at Bolt, Beranek and Newman, Inc. of Cambridge, Massachusetts, in conjunction with the U.S. Navy as a computerized game to aid teachers in developing strategies for coping with the possible range of student error patterns in addition and subtraction computations. The computer simulates the part of the errant student, and the computer user is the diagnostician. The diagnostician is shown several problems the "student" has completed incorrectly. By providing additional problems or asking for more examples, the

diagnostician must discover the underlying misconception. The computer answers the additional problems and examples using the faulty algorithm just as the student would.

The following protocal is a modification of that provided by Brown and Burton in their report to Bolt, Beranek,and Newman concerning Buggy.

```
WELCOME TO BUGGY.
I HAVE CHOSEN A BUG.  HERE IS AN EXAMPLE OF THE BUG.

17
+5
--
13

NOW YOU CAN GIVE ME PROBLEMS TO DETERMINE THE BUG.

18     43
+6    +79
--    ---
15     23
```

The user generates the problem, and the "student" answers it.

```
GOT THE BUG!
```

The user indicates to the system that he has an initial hypothesis. The system asks the user to describe the bug, and then the user is tested. No attempt is made to judge the description.

```
PLEASE DESCRIBE THE BUG.

"Student adds the number to be carried into the last
column worked in."
```

This description is typical of the difficulty in describing error patterns, but it helps the user visualize the pattern. To make sure the description is correct a quiz of up to five problems is given.

```
HERE ARE SOME PROBLEMS TO TEST YOUR THEORY ABOUT THE
BUG.
WHAT IS:

 21
+39
---
 51
```

The user answers 51 which is incorrect. Buggy <u>presents</u> its answer and then allows the user to enter more problems.

```
THAT'S NOT THE BUG I HAVE.
USING MY BUG:

 21
+39
---
 15

TRY GIVING ME SOME MORE PROBLEMS.

   51      99     68
+1707     +99     +9
-----     ---     --
   21      36     23
```

After failing the quiz, the user enters several more problems which the "student" answers. Now the user has a better hypothesis and decides to guess again.

GOT THE BUG!

PLEASE DESCRIBE THE BUG YOU THINK I HAVE.

"The student is adding all the digits together."

HERE ARE SOME PROBLEMS TO TEST YOUR THEORY ABOUT THE BUG.
WHAT IS:

33	1091	8	28	90
+99	+60	+34	+70	+6
24	17	15	17	15

VERY GOOD. MY DESCRIPTION OF THE BUG IS:
THE STUDENT ALWAYS SUMS UP ALL THE DIGITS WITH NO REGARD TO COLUMNS.

This time the user was correct and answered all five problems. *Buggy* gives its own description of the bug for comparison with the user's description. The user is then asked if he or she wishes to continue. If so, the procedure begins again with a different bug.

Synthesis of the Related Research

Three distinct areas of literature were presented as relevant to this investigation; yet, no single work or study incorporated all three areas. The purpose of this section is to present a blend of these areas.

In the section concerning the background of the problem, theories were presented concerning the need to allow for individual differences among students by offering

compatible instructional strategies. The strategy of importance in this investigation was the use of the microcomputer to aid in learning to identify student errors in addition and subtraction. From direct observation two types of individual differences were emphasized: the strategy used by the subject to detect error patterns and the subject's conceptual tempo. The computer lesson <u>Buggy</u> was used to incorporate all of these areas for this investigation.

CHAPTER III
PROCEDURES

The purpose of this study was to identify specific patterns characteristics of 40 pre-service elementary teachers enrolled in preparatory programs at the University of Florida and to relate those characteristics to achievement on a posttest. Each subject worked with the computer lesson _Buggy_ and took a posttest on identifying error patterns in addition and subtraction. The subjects had previously been tested to identify their conceptual tempo. The data derived from the investigation were analyzed to determine if significant differences existed between subjects using different strategies with _Buggy_ in relationship to their conceptual tempo. The purpose of this chapter is to detail the procedures followed in this investigation.

Pilot Study

A pilot study was conducted to identify potential characteristics which might predict achievement and to field test the computer lesson _Buggy_. Four pre-service elementary teachers were chosen from the Childhood Education Program elementary mathematics methods class. These subjects were

given credit for one of the activities required in their methods class. A brief verbal description of how Buggy functioned was given prior to the subject's interaction with the computer lesson. Each subject worked through the computer lesson individually and was told to work until the subject felt comfortable identifying error patterns.

The investigator was present at each of the sessions providing technical assistance where necessary. In addition to serving as general guide, the investigator kept a log of the subject's direct interaction with the computer lesson. A record was kept of the subject's physical actions while at the computer terminal and the dialogue with the investigator. The log recorded the number and type of error patterns with which the subject interacted, the time spent on each pattern, the number of problems the subject gave the computer, the number of times the subject requested additional examples, and the number of quizzes which were attempted or completed.

The following table represents the basic results of the pilot study log:

TABLE 1

PILOT STUDY: MEANS AND RANGES

VARIABLES	MEAN	RANGE
Time in Minutes	53	42 - 63
Bugs Attempted	10	7 - 15
Examples Requested	23	7 - 55
Problems Given	26	6 - 47
Quizzes Taken	15	10 - 17

After taking the ranges into consideration, the strategies the subjects used in trying to determine the error pattern seemed to fall into predominate categories. These categories consisted of asking for additional examples, giving the computer test problems, taking quizzes, or no dominate method. At the same time, the notes concerning the subject's verbal interaction with the investigator demonstrated the subject's concern with time and accuracy. This concern lead to the idea of using conceptual tempo. These two characteristics, type of strategy and conceptual tempo, became the focus of the present investigation.

Alterations to Buggy

The pilot study also indicated that the computer lesson *Buggy* was too long for the allowable time frame. *Buggy* contained eleven subtraction and eight addition error patterns. Since these patterns came up randomly, there was no control over which error patterns an individual subject might deal with in a given time. Consequently, there was no control over the posttest. If such was the case, comparison of posttest scores would be meaningless. Accordingly, a subroutine was added to *Buggy* which limited the possible error patterns to the following six.

Addition:

> Addends are aligned to the left rather than to the right.
>
> The sum of all the digits is determined regardless of place value.
>
> When the sum of a column is ten or greater, the digit that should be carried is added into the same column rather than carried to the next column.

Subtraction:

> When regrouping is necessary, one 10 (or one 100) is not subtracted from the next column.
>
> The smaller digit in each column is subtracted from the larger except when the minuend is zero, in which case a zero is placed in the difference.
>
> When regrouping is necessary, all borrowing is done from the leftmost digit of the minuend.

With this alteration, two goals were reached. First, the amount of time each subject had to spend on the computer lesson was limited to less than an hour and a half. Second, each subject was assured of having worked with some of the items on the posttest.

Description of the Subjects

The 43 subjects who participated in the study were prospective teachers in the Childhood Education Program at the University of Florida and were enrolled in the elementary mathematics methods course. Permission to conduct the

investigation was given by the faculty director of the elementary mathematics program, and credit was given to the subjects for the computer lesson time as one of the activities for the Addition and Subtraction Module required in their methods class.

Data were missing for three of the subjects including the data on the only male involved in the study. The 40 subjects for whom complete sets of data were obtained were all female. The median age was 21.5, and the mean age was 23 with a range of 20 to 40. Of the 40 subjects, 68% had had only the elementary mathematics course for teachers at the university. Two-thirds of the subjects had not had any prior experience with a computer. The other third had taken the Computers in the Classroom Module in their methods class. This module did not teach any technical skills, but did familiarize the subjects with the use of the operation of the microcomputer.

Data Collection

Four to six weeks before completing the computer lesson, the subjects were given the Matching Familiar Figures Test to identify their conceptual tempo. This test consisted of 12 items in which they were to match a picture of a familiar object on the first page to one of eight similar items on the second page. The time from the subject's first glance

at each item to the first guess was recorded along with the number of incorrect guesses. These categories were then rank ordered from least to greatest. A subject who ranked below the median time to first guess and above the median number of incorrect guesses was classified fast-inaccurate and labeled impulsive (N = 12), a subject who ranked above the median time to the first guess and below the median number of incorrect guesses was classified slow-accurate and labeled reflective (N = 9). For the purposes of this investigation, subjects who ranked fast-accurate, slow-inaccurate, or subjects whose rankings were on the median were labeled "neither" (N = 19).

The University of Florida, College of Education Computer Laboratory contained eight Apple II Plus computers. The subjects were given an introductory sheet on <u>Buggy</u> (see Appendix A). This sheet contained an explanation of the importance of <u>Buggy</u> and general instruction for interacting with the program. Six to eight subjects attended the laboratory at one time. The investigator was present at each of these sessions. In addition to giving general instructions, the investigator provided guidance to subjects who requested help. If a subject requested help, the investigator suggested that the subject begin with basic

arithmetic facts, such as 3 + 4, continue with facts that required regrouping such as 9 + 8, give the computer problems with two digit addends, and continue with slightly more difficult problems until the first error was detected.

Each subject's interaction with Buggy was recorded in two ways. First, each subject was asked to keep a log of her exchanges with Buggy (see Appendix E). Second, a subroutine was attached to Buggy which recorded all the data the subject had entered into the computer. The amount of data each individual could enter was theoretical; however, if the memory limit was reached, the program failed and all data were lost. Because of this problem the investigator collected data following the completion of each error pattern, before the memory limit was reached. Incomplete subject logs and computer "failures" resulted in the loss of data for three subjects. Forty subjects had data which were reliable enough for use in this study.

When each subject decided she had worked with Buggy long enough to feel comfortable in identifying error patterns, she was given a posttest (see Appendix B). At that time, each subject was asked if she had had any previous contact with diagnosis of error patterns. The response was negative in each case. The posttest contained five addition

and five subtraction error patterns. All six of the patterns available in the computer program Buggy were represented. Four patterns (problems 2, 4, 7, and 9) which the subjects had never seen before were also included. These error patterns were the following:

Addition:

> The ones, tens, and hundreds digits are added and recorded in the sum without regard to place value.
>
> If one addend has fewer digits than the other, the leftmost digit of the smaller addend is repeated to the left so both addends will have the same number of digits.

Subtraction:

> The smaller digit in each column is subtracted from the larger digit.
>
> The basic fact that A - 0 = A is understood as A - 0 = 0.

Six error patterns were presented as sets of problems (numbers 1, 2, 3, 6, 7, and 8) in which the subject was asked to complete three additional problems using the same error pattern. Four error patterns were presented in the same manner, but the subject was asked to find the one description which best fit that error pattern (numbers 4, 5, 9, and 10).

The posttests were checked, and the following three scores were calculated: (1) the total percentage of problems answered correctly; (2) the percentage of correct problems

which were derived from error patterns with which the subject had previously worked; and (3) the percentage of correct problems derived from error patterns not previously seen by the subject. Thus, each subject had a posttest score, a score for tried error patterns, and a score for untried error patterns.

Following completion of the posttest scoring, the subject logs and the data saved by the computer were compared and analyzed. The computer saved data were considered the most important, and the subject logs were used only if that subject's program had failed. If there was any doubt about the subject log which could not be verified by the computer data, that subject's data were not included in the study (N = 3).

The data collected represented the number and type of error patterns with which the subject had worked, the amount of time the subject had spent working with the computer program Buggy, the number of examples requested, the number of test problems given the computer, and the number of quizzes requested by the subject. The subjects were then classified by their predominant strategy ("examples," "problems," or "quizzes") by comparing the number of examples requested, the number of test problems given, and the number of quizzes

requested to that particular mean for the entire study. If the subject's total was a half standard deviation above the mean for that strategy, she was classified as predominantly using that strategy. Of the 40 subjects, six were classified as using examples, nine as using test problems, and three as using quizzes. If two or more strategies were a half standard deviation above the mean, the strategy farthest from its mean was chosen. If none of the strategies was above the group mean, the subject was placed in a fourth classification labeled "none." These subjects totaled 22.

At the conclusion of the data collection, each subject had a posttest score, a score, tried, for the patterns with which she had worked using Buggy, and a score, untried, for the patterns which she had not seen before. All three of these scores were based on the percentage of problems answered correctly in that category. Each subject's conceptual tempo had been recorded as reflective, impulsive, or neither. And, each subject had been classified as to the predominant strategy used in determining error patterns presented by Buggy. These strategies were labeled as example, problem, quizzes, or none. Chapter IV describes the statistical tests used to analyze these data.

CHAPTER IV
ANALYSIS AND INTERPRETATION OF THE DATA

The primary objective of this investigation was to determine if a relationship exists between the conceptual tempo and predominant strategy of a subject and achievement on a posttest following a computer lesson. Chapter IV provides a summary of the data, describes the statistical tests used to reject the hypotheses, and interprets the results of the statistical tests. Following the collection and compilation of the data, as described in Chapter III, the hypotheses for each dependent variable were tested using the Statistical Analysis System (SAS). Computing was done using the facilities of the Northeast Regional Data Center of the State University System of Florida, located on the campus of the University of Florida in Gainesville.

Distribution of Scores Within Variables

The means, standard deviations, and distributions of the dependent and independent variables were compiled for the study (see Table 2). In addition to the total posttest score, each subject was given a score, labeled tried, for that portion of the posttest derived from error patterns with which the subject had worked on the computer lesson

TABLE 2

DISTRIBUTION OF THE SCORES WITHIN VARIABLES

Variable	N	Mean	Standard Deviation	Range
Posttest	40	86.18	11.98	50 - 100
Tried	40	85.3	15.84	25 - 100
Untried	40	86.45	13.88	54 - 100
No. of Bugs	40	4.6	1.24	2 - 6
Time	40	55.4	17.71	31 - 109
Time/Bug	40	12.86	5.68	5 - 39
Examples	40	13.1	6.37	4 - 29
Problems	40	17.21	12.44	2 - 43
Quizzes	40	8.93	3.48	3 - 16

and a score, labeled untried, for that portion of the posttest consisting of previously unknown error patterns. The means for the total posttest scores, the scores on the previously tried items, and the scores for the untried items were between 85 and 87. The mean number of minutes working on the computer lesson was 55. Of the six error patterns available in Buggy, the subjects worked with a mean of five. The three strategies focused on in this study were the number of examples requested (mean: 13, range: 4 to 29); the number of test problems given Buggy (mean: 17, range: 2 to 43); and the number of quizzes requested (mean: 3, range: 3 to 16).

Intercorrelations Between Variables

Intercorrelations of independent and dependent variables were compiled for the study (see Table 3). The highest correlations were between the subsets of the posttest score, tried and untried, and the total score. This correlation of 0.55 was expected because these variables are not independent of each other. The amount of time spent working with Buggy and the number of error patterns covered had a correlation of 0.31. This correlation appears to indicate that the strategy used by the subject was of some importance. However, the correlations between strategies were all negative but not significant.

TABLE 3

INTERCORRELATIONS BETWEEN VARIABLES

Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Posttest	1.00	0.82	0.91	0.17	-0.18	-0.16	-0.25	-0.14	-0.16
2. Tried		1.00	0.55	0.22	-0.14	-0.22	-0.09	-0.07	-0.09
3. Untried			1.00	0.17	-0.08	-0.10	-0.25	-0.18	-0.21
4. No. of Bugs				1.00	0.31	-0.55	0.37	0.39	0.56
5. Time					1.00	0.52	0.23	0.49	0.30
6. Time/Bug						1.00	-0.13	-0.01	-0.15
7. Examples							1.00	0.10	0.05
8. Problems								1.00	0.32
9. Quizzes									1.00

Hypotheses I, II, and III

In the first set of hypotheses, the total posttest score is the independent variable, achievement.

Hypothesis I
There is no interaction between the strategy and conceptual tempo of a subject on the total posttest score.

A regression model was used to test for interaction of strategy and conceptual tempo. Both strategy and conceptual tempo were treated as independent blocking variables. The generated frequency table showed three empty cells (see Table 4). Empty cells are typical of studies using attribute variables (Kerlinger and Pehauzer, 1973, p. 7). Because a regression model requires subjects in each cell, a formula which integrated the speed and accuracy scores of the MFFT was used to transform conceptual tempo into a continuous variable called efficiency. The efficiency score was calculated by multiplying the subject's total errors by 100 and adding this to the subject's response time total. "Efficiency = response time + (errors X 100)" (Young, 1973, p. 9). The regression model was: ACHIEVEMENT = STRATEGY + EFFICIENCY + (STRATEGY EFFICIENCY).

An analysis of the residuals showed that the plots did not have a shape and that the model was linear. Comparing the full model to a reduced model without the interaction

TABLE 4

STRATEGY VS. CONCEPTUAL TEMPO
(Frequency and Percentage)

	Frequency Percent	Conceptual Tempo Impulsive	Neither	Reflective	TOTAL
Strategy	Examples	2 5.00%	0 0.00%	4 10.00%	6 15.00%
	Problems	1 2.50%	7 17.50%	1 2.50%	9 22.50%
	None	6 15.00%	12 30.00%	4 10.00%	22 55.00%
	Quizzes	3 7.50%	0 0.00%	0 0.00%	3 7.50%
	TOTAL	12 30.00%	19 47.50%	9 22.50%	40 100.00%

term showed that the interaction term was not significant (see Table 5). Because the interaction term was not significant in the regression model, Hypothesis I could not be rejected.

Accordingly, a new model was used to test Hypotheses II and III:

ACHIEVEMENT = STRATEGY + EFFICIENCY.

Hypothesis II
There are no differences among those subjects classified as impulsive, reflective, or neither on the total posttest score.

Hypothesis III
There are no differences on the total posttest score among subjects who used different strategies in finding error patterns.

The strategy used by the subject to find error patterns was not related to achievement as represented by the posttest scores (see Table 6), and Hypothesis II cannot be rejected. The efficiency score was related (0.01 level) to the posttest score (see Table 6), and Hypothesis III was not accepted.

As a further check on these results, a one-way analysis of variance was used with the original independent variable and strategy against the total posttest score. Conceptual tempo was used because there was no longer a danger of empty cells. The results (see Table 7) of the one-way analysis of variance supported the previous findings concerning Hypotheses II and III.

TABLE 5

INTERACTION OF STRATEGY AND EFFICIENCY
ON TOTAL POSTTEST SCORE

Source of Variation	DF	Sum of Squares	F Value	Probability > F
Strategy	3	108.38	0.27	0.8442
Efficiency	1	437.21	3.31	0.0783
Strategy*Efficiency	3	250.02	0.63	0.6007
Error	32	4229.38		

TABLE 6

SIGNIFICANCE OF STRATEGY AND EFFICIENCY ON TOTAL POSTTEST SCORE

Source of Variation	DF	Sum of Squares	F Value	Probability $> F$
Strategy	3	369.67	0.96	0.4211
Efficiency	1	1038.29	8.11	0.0073*
Error	35	4479.40		

* $\underline{p} < .01$

TABLE 7

SIGNIFICANCE OF STRATEGY AND CONCEPTUAL TEMPO ON TOTAL POSTTEST SCORE

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Probability $> F$
Strategy					
Model	3	78.08	26.03	0.17	0.9161
Error	36	5517.70	153.27		
Conceptual Tempo					
Model	2	1243.23	621.62	5.28	0.0096*
Error	27	4352.54	117.64		

* $p < .01$

Because conceptual tempo was significant, in the follow-up analysis (see Table 8) or post hoc comparisons concerning conceptual tempo, the Dunn Comparison Procedure was used (Kirk, 1968). The mean posttest score for the reflective subjects was significantly higher (0.05 level) than the mean for the impulsive subjects. There was not a significant difference between the scores of the subjects labeled impulsive or reflective and the subjects who were classified as neither.

Hypotheses IV, V, and VI

For the independent variable achievement, Hypotheses IV, V, and VI used the score of the portion of the posttest derived from error patterns with which the subjects had previously worked. The same statistical procedures were used in testing Hypotheses IV, V, and VI as were used with the first set of hypotheses.

Hypothesis IV
There is no interaction between the strategy and the conceptual tempo of a subject on the score of the portion of the posttest derived from error patterns with which the subjects had previously worked.

The regression model, using efficiency in place of conceptual tempo, was used to test for the significance of the interaction term. Following an analysis of the residuals for a linear model, the full model was compared to a reduced model. The interaction term was not significant (see Table 9), and Hypothesis IV was not rejected.

TABLE 8

COMPARISON OF SUBJECTS BY CONCEPTUAL TEMPO ON TOTAL POSTTEST SCORE

Group:	Reflective	Neither	Impulsive
	N = 9	N = 19	N = 12
Mean:	94.78	86.47	79.25

Dunn Multiple Comparison Procedure

The scores of the underlined groups are not significantly different. The scores of the reflective group are significantly different than the scores of the impulsive group at the 0.01 level.

TABLE 9

INTERACTION OF STRATEGY AND EFFICIENCY
ON ERROR PATTERNS PREVIOUSLY TRIED

Source	DF	Sum of Squares	F Value	Probability F
Strategy	3	124.92	0.17	0.9153
Efficiency	1	720.39	2.96	0.0952
Strategy*Efficiency	3	206.32	0.28	0.8378
Error	32	7798.01		

Hypothesis V
There are no differences among those subjects classified as impulsive, reflective, or neither on the score of the portion of the posttest derived from error patterns with which the subjects had previously worked.

Hypothesis VI
On the score of the portion of the posttest derived from error patterns with which the subjects had previously worked, there are no differences among subjects who used different strategies in finding error patterns.

Following the testing of the reduced model (see Table 10), strategy was not found to be related to achievement on that part of the posttest consisting of error patterns from Buggy. Hypothesis V could not be rejected. Efficiency was significant (0.05 level), and Hypothesis VI was not accepted. A one-way analysis of variance confirmed the above findings (see Table 11).

In the follow-up analysis for conceptual tempo (see Table 12), the mean of the tried problems for the reflective subjects was significantly higher (0.01 level) than the mean for the impulsive subjects. The mean for the subjects labeled neither was significantly higher (0.01 level) than the mean for the impulsive subjects. There was no significant difference between the subjects classified as neither and as reflective.

Hypotheses VII, VIII, and IX

As the independent variable, achievement, Hypotheses VII, VIII, and IX used the portion of the posttest score derived

TABLE 10

SIGNIFICANCE OF STRATEGY AND EFFICIENCY ON ERROR PATTERNS PREVIOUSLY TRIED

Source of Variation	DF	Sum Squares	F Value	Probability $> F$
Strategy	3	311.06	0.45	0.7166
Efficiency	1	1403.03	6.13	0.0182*
Error	35	8004.33		

* $p < .01$

TABLE 11

SIGNIFICANCE OF STRATEGY AND CONCEPTUAL TEMPO ON ERROR PATTERNS PREVIOUSLY TRIED

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Probability > F
Strategy					
Model	3	375.04	125.01	0.48	0.6993
Error	36	9407.36	261.32		
Conceptual Tempo					
Model	2	2899.40	1449.70	7.79	0.0015*
Error	37	6882.40	186.03		

* $\underline{p} < .01$

TABLE 12

COMPARISON OF SUBJECTS BY CONCEPTUAL TEMPO ON ERROR PATTERNS PREVIOUSLY TRIED

Group:	Reflective	Neither	Impulsive
Mean:	N = 9 94.56	N = 19 88.84	N = 12 72.75

Dunn Multiple Comparison Procedure

The scores of the underlined groups are not significantly different. The scores of the reflective group are significantly different than the scores of the impulsive group at the 0.01 level, and the scores of the neither group are significantly different than the scores of the impulsive group at the 0.01 level.

from error patterns with which the subjects had not previously worked. This set of hypotheses was tested using the same set of statistical procedures as were the previous sets of hypotheses.

Hypothesis VII
There is no interaction between the strategy and conceptual tempo of a subject on the score of the portion of the posttest derived from error patterns with which the subjects had not previously worked.

Following the analysis of the residual plots for linearity, the regression model was used to test for the interaction of strategy and efficiency (see Table 13). The interaction term was eliminated, and Hypothesis VII could not be rejected.

Hypothesis VIII
There are no differences among those subjects classified as impulsive, reflective, or neither on the score of the portion of the posttest derived from error patterns with which the subjects had not previously worked.

Hypothesis IX
On the portion of the posttest score derived from error patterns with which the subjects had not previously worked, there are no differences among subjects who used different strategies in finding error patterns.

The reduced model tested for the significance of strategy and efficiency (see Table 14). Strategy was not found to be significant. Hypothesis VIII was not rejected. Efficiency was significant (0.05 level), and Hypothesis IX was not

TABLE 13

INTERACTION OF STRATEGY AND EFFICIENCY
ON ERROR PATTERNS PREVIOUSLY UNTRIED

Source of Variation	DF	Sum of Squares	F Value	Probability > F
Strategy	3	358.05	0.65	0.5888
Efficiency	1	122.44	0.67	0.4202
Strategy*Efficiency	3	585.50	1.06	0.3785
Error	32	5875.64		

TABLE 14

SIGNIFICANCE OF STRATEGY AND EFFICIENCY ON ERROR PATTERNS PREVIOUSLY UNTRIED

Source of Variation	DF	Sum of Squares	F Value	Probability $> F$
Strategy	3	625.63	1.13	0.3504
Efficiency	1	920.29	4.99	0.0321*
Error	35	6461.13		

* $\underline{p} < .05$

accepted. A one-way analysis of variance was used to check the findings, but conceptual tempo had a 0.06 level of significance (see Table 15).

In the post hoc comparisons using the Dunn Procedure, the mean of the untried problems on the posttest for the reflective subjects was significantly higher (0.05 level) than the mean for the impulsive subjects. There was no significant difference between the subjects classified as neither and the subjects classified as reflective or impulsive (see Table 16).

Interpretation of the Data

The analysis indicated that the strategies identified in this study did not affect the posttest scores. The subject who relied on the strategy of requesting examples did no better on achievement on the posttest than did the subject who mainly gave the computer test problems or the subject who predominately requested quizzes. These results also applied to those portions of the posttest labeled tried and untried. Application of knowledge to new problems, represented by the untried problems on the posttest, was not related to a subject's predominant strategy on the computer program _Buggy_.

TABLE 15

SIGNIFICANCE OF STRATEGY AND CONCEPTUAL TEMPO ON ERROR PATTERNS PREVIOUSLY UNTRIED

Source of Variation	DF	Sum of Squares	Mean Squares	F Value	Probability > F
Strategy					
Model	3	128.48	42.83	0.21	0.8896
Error	36	7381.42	205.04		
Conceptual Tempo					
Model	2	1048.11	524.06	3.00	0.0620
Error	37	6461.79	174.64		

TABLE 16

COMPARISON OF SUBJECTS BY CONCEPTUAL TEMPO
ON ERROR PATTERNS PREVIOUSLY UNTRIED

Group:	Reflective	Neither	Impulsive
Mean:	N = 9 95.67	N = 19 84.89	N = 12 82.00

Dunn Multiple Comparison Procedure

The scores of the underlined groups are not significantly different. The scores of the reflective group are significantly different than the scores of the impulsive group at the 0.05 level.

The conceptual tempo of a given subject did have a relationship with achievement on the total posttest score. Reflective subjects scored significantly better on the post hoc comparisons than did impulsive students on the total posttest (0.01 level). The same results applied to the tried and untried portions of the posttest. Conceptual tempo significantly affected achievement in rote learning, as represented by the tried problems of the posttest, and in applying knowledge to the new problems as represented by the untried problems on the posttest. The follow-up analyses resulted in reflective subjects scoring significantly better than impulsive subjects at the 0.01 and 0.05 levels, respectively.

Conceptual tempo as represented by an efficiency score was significant at the 0.05 level. The efficiency variable was a standardized score used to make conceptual tempo a continuous variable. High efficiency scores were typical of impulsive subjects, while reflective subjects received low efficiency scores. As a continuous variable, efficiency scores more accurately predicted achievement than did the blocking variable conceptual tempo. The difference in significance levels of conceptual tempo and efficiency

0.03 and 0.06, respectively) on the untried portion of the posttest might be accounted for in this way. Otherwise, conceptual tempo and efficiency gave similar results.

One individual characteristic of a subject using the microcomputer to learn to identify error patterns in addition and subtraction was identified as a predictor of achievement on a posttest. That characteristic was conceptual tempo. The implications of these findings are presented in Chapter V.

CHAPTER V
IMPLICATIONS

The purpose of this chapter is to present the implications of the findings in the present study. Based upon the analysis of the data concerning pre-service elementary teachers in the Childhood Education Program at the University of Florida, significant differences were established between subjects classified by conceptual tempo. The classification of impulsive and reflective were significant on achievement on a posttest following a computer lesson designed to teach error patterns in addition and subtraction computations. Before the implications are presented, an overview of a higher achieving individual will be presented.

The typical individual who scored higher on the posttest following completion of the computer lesson Buggy had a reflective, rather than impulsive, conceptual tempo. A reflective subject is one who makes fewer errors than the sample median and whose mean latency to first response is larger than the sample median on the Matching Familiar Figures Test. The same subject did not have a recognizable pattern of approach in dealing with Buggy which could be used to predict achievement.

Implication for the Classroom

The immediate implications of this investigation for the classroom teacher are clear. Given the reasonable postulates that (a) individual differences exist among students and (b) educational strategies designed to meet the requirements of the individual are most effective, a teacher's in-depth knowledge of a student is paramount to effect maximum instruction. For the teacher with a classroom computer, the knowledge of a student must include the student's conceptual tempo. The classroom teacher must be aware that some students using the computer in a given learning situation achieve to a higher degree than do other students.

The teacher should also be aware that students have dominant strategies in problem solving situations. While this study did not identify a predominant strategy which predicted achievement, some subjects when given a choice of several strategies chose to use one strategy to the exclusion of any other strategies. Thus, classroom teachers should be aware that students may have to be persuaded to try different problem solving strategies.

Implication for Future Research

This investigation was designed to answer three questions. The answers to these questions have implications for future research.

Question 1:

> While using the computer lesson Buggy, do the subjects exhibit certain behaviors or traits which can be used to predict achievement?

The answer to that question is yes. Subjects do exhibit certain behaviors or traits which can be used to predict achievement. But that answer is not of value unless those behaviors can be identified. The next two questions address specific behaviors.

Question 2:

> Is there a difference in achievement among subjects who mainly request examples, subjects who mainly give the computer test problems, and subjects who mainly use quizzes to determine the error patterns in Buggy?

The answer to question 2 is no. No single strategy identified in this study related to achievement. However, there may be a combination of strategies which is best. To completely discount strategy as a variable would be a mistake. Further research is needed to investigate strategy as a characteristic used to predict achievement.

Question 3:

> Is there a difference in achievement among subjects who are impulsive, reflective, or neither?

The answer to question 3 is yes. The extent to which the findings of the present study can be applied are limited. The subjects consisted of 40 pre-service elementary teachers

at the University of Florida. Future research must investigate if the results achieved with Buggy are generalizeable to larger samples of pre-service elementary teachers at other institutions. The computer lesson Buggy is of general use primarily to mathematics educators. But, Buggy could be used at any level of mathematics instruction. Consequently, the present study should be replicated with a variety of subjects.

Since the results of this study center around the computer lesson Buggy, new investigations should determine if the present findings extend to other computer lessons. If the results are not generalizeable to other computer lessons, the critical sections of Buggy must be identified to determine what in Buggy's nature appeals to reflective subjects. If the results are generalizeable to other forms of computer lessons, research must identify the attributes of these lessons.

Computer lesson attributes are the key to the knowledge of whether programs can be manipulated to increase the achievement of impulsive subjects. If the subjects had been required to spend a certain amount of time on individual error patterns, impulsive subjects might have been forced to slow down and overcome their preoccupation with being fast. If accuracy is stressed and speed is ignored,

impulsive children can be trained to be more reflective (Nelson, 1968). Other attributes of the computer lesson, such as providing a more tutorial approach explaining individual error patterns or giving more drill and practice, could also be of influence.

Of greater importance is the general application using the computer to manipulate learning experiences to capitalize on individual characteristics to increase achievement. Suppose that a number of individual characteristics were identified that when matched with specific computer attributes increased achievement. The subject beginning a computer lesson could start by identifying herself/himself to the computer which would key the program to that subject's characteristics. With each characteristic, the computer would connect the best subroutine into the lesson which would effect optimal achievement. Thus, through branching to a catalog of subroutines which account for each program attribute, a truly personalized teaching strategy could be developed to perfectly fit each individual.

The purpose of this investigation was to identify specific individual characteristics of subjects using a computer lesson and to relate those characteristics to achievement. One

characteristic, conceptual tempo, was found. Reflective subjects achieved significantly higher than impulsive subjects on the posttest. Future research should: (1) replicate this study with larger and/or different samples; (2) discover other individual characteristics which relate to achievement on a computer lesson; (3) identify the attributes of computer lessons; and (4) match individual characteristics with corresponding computer lesson attributes to effect maximum achievement.

APPENDIX A
DIRECTIONS FOR BUGGY

DIAGNOSIS OF ERROR PATTERNS IN ADDITION AND SUBTRACTION

Suppose the process of addition has already been taught to your class. When a child misses an addition problem, and you mark it wrong, what do you do next? If it is the only one missed, you might assume it was accidental error. But what if a large percentage of the problems are missed? A typical response might be to re-teach the entire unit. But this is not very efficient. Instead you should diagnose the problem and then seek to prescribe activities which will remediate that particular difficulty.

Buggy is a computer lesson designed to teach diagnosis of error patterns in addition and subtraction. It helps develop skill in finding out what is causing a student to make arithmetic mistakes. The computer will pretend to have a "bug" in its arithmetic procedure which causes it to give wrong answers. An example of a bug is "to forget to borrow." You are to discover what the bug is by giving the computer some test problems and analyzing the computer's answers. If you enter the wrong digit, the left arrow erases that digit.

Your options are:

Give the computer problems to solve;

Type "M" for more examples of the bug;

Type "G" to guess the bug and to take a quiz;

Type "Q" to give up and let the computer explain the bug.

When you type "G" the computer will ask you to describe the bug you found in order to clarify your ideas. A period will notify the computer you have finished your description of the bug. The computer will then give you several problems

to test your descriptions. If you get any wrong, the computer will ask for more practice problems. If you get them right, the computer will confirm your description of the bug by giving one of its own.

Do as many bugs as you think necessary to familiarize yourself with the different error patterns in Buggy. There are six different bugs. After you have finished, a short posttest will be given to determine your understanding of Buggy's bugs.

APPENDIX B
POSTTEST FOR BUGGY

DIAGNOSIS OF ERROR PATTERNS IN ADDITION AND SUBTRACTION
POSTTEST

Date:____________________ Name:______________________________

Before working with Buggy, had you ever tried to find error patterns in addition or subtraction?

Compute the unsolved problems using the same error pattern:

1.

352	25	342	118	607	18	305	12
+18	+7	+50	+325	+ 2	+4	+26	+85
532	95	842	443	807			

2.

74	35	67	56	318	43	88	7
+56	+92	+18	+97	+293	+65	+39	+14
1210	127	715	1413	51011			

3.

17	84	51	30	612	47	20	518
+5	+28	+8	+70	+236	+1	+998	+113
13	22	14	10	20			

Find the description which best fits the error pattern represented by the sample problems:

4.

352	37	251	321	708
+18	+8	+60	+117	+ 3
470	125	911	438	1041

A. When the bottom number has fewer digits than the top number, the bottom number is left justified.

B. The units digit is written in the answer and the carry digit is carried.

C. The left digit of the bottom number is repeated to the left to make the two numbers have the same number of digits.

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D. All of the carries are added to the left most column.

E. I can't find the correct description.

5.	17	26	9	813	68
	+5	+83	+83	+383	+31
	13	19	83	296	99

A. The answer is the sum of all the digits without attention to place value.

B. When carrying, the carry is added to the same column.

C. The columns are added from left to right and carrying is to the right.

D. All of the carries are added to the units column.

E. I can't find the correct description.

Compute the unsolved problems using the same error pattern:

6.	250	40	203	7083	83	10	57	2068
	-160	-7	-98	-4009	-79	-7	-9	-1799
	110	40	205	3086	16			
7.	17	329	55	1982	150	12	502	83
	-8	-132	-47	-693	-69	-9	-185	-66
	11	217	12	1311	119			
8.	850	51	611	5060	8333	2951	994	602
	-376	-23	-537	-527	-3727	-676	-25	-137
	384	28	CANT	3543	3616			

Find the description which best fits the error pattern represented by the sample problems:

9.

147	624	527	805	115
-20	-323	-304	-201	-10
120	301	203	604	100

A. The fact that A - 0 = A is misunderstood as A - 0 = 0.

B. In the columns where borrowing is necessary, 0 is written in the answer.

C. If the bottom digit is zero, the bottom digit is written; otherwise, if borrowing is needed, zero is written.

D. I can't find the correct description.

10.

103	70	22	200	1795
-68	-54	-6	-157	-259
145	26	26	153	1546

A. Borrows are made from the bottom digit of the next number, and zeros in the same column are changed to nines.

B. When borrowing, ten is added to the top number, but one is not subtracted from the next column.

C. Borrowing is not done except if the top digit is zero.

D. I can't find the correct description.

APPENDIX C
MFFT DATA COLLECTION SHEET

NAME: ______________________ S.S. #____________________

ADDRESS: ____

PHONE: ______________ AGE: ____________________

SEMINAR LEADER: ________________________________

MATHEMATICS BACKGROUND: (CIRCLE THE COURSES TAKEN)

HIGH SCHOOL: ALGEBRA I ALGEBRA II GEOMETRY
TRIGONOMETRY CALCULUS

COLLEGE: ALGEBRA TRIGONOMETRY GEOMETRY
CALCULUS I II III
MAE 3810 MAE 3811
OTHER: ______________________

	Time	Error
1.	____	____
2.	____	____
3.	____	____
4.	____	____
5.	____	____
6.	____	____
7.	____	____
8.	____	____
9.	____	____
10.	____	____
11.	____	____
12.	____	____

AVERAGE NUMBER OF SECONDS: __________

TOTAL NUMBER OF ERRORS: __________

CLASSIFICATION: __________

EFFICIENCY SCORE: __________

APPENDIX D
DATA SUMMARY SHEET

SUBJECTS:	1.	2.	3.	.....
NUMBER OF BUGS ATTEMPTED:				
NUMBER OF ADDITION BUGS:				
NUMBER OF SUBTRACTION BUGS:				
TOTAL TIME AT COMPUTER:				
AVERAGE TIME PER BUG:				
STRATEGY:				
TOTAL EXAMPLES REQUESTED:				
EXAMPLES PER BUG:				
TOTAL TEST PROBLEMS GIVEN:				
TEST PROBLEMS PER BUG:				
TOTAL QUIZZES REQUESTED:				
QUIZZES PER BUG:				
POSTTEST SCORE:				
TRIED:				
UNTRIED:				
MFFT CLASSIFICATION:				
EFFICIENCY SCORE:				
AGE:				

APPENDIX E

SUBJECT LOG

NAME: ______________________________________

DATE: __________ TIME IN: __________ TIME OUT: ____________

BUG NUMBER:

NUMBER OF TEST PROBLEMS GIVEN:

NUMBER OF EXAMPLES GIVEN:

NUMBER OF GUESSES (QUIZZES):

EXPLANATIONS:

BUG NUMBER:

NUMBER OF TEST PROBLEMS GIVEN:

NUMBER OF EXAMPLES GIVEN:

NUMBER OF GUESSES (QUIZZES):

EXPLANATIONS:

BUG NUMBER:

NUMBER OF TEST PROBLEMS GIVEN:

NUMBER OF EXAMPLES GIVEN:

NUMBER OF GUESSES (QUIZZES):

EXPLANATIONS:

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BIOGRAPHICAL SKETCH

Ken was born on May 21, 1950, in Clovis, New Mexico, the son of Kenneth and JoAnn Henderson. With his brother Shawn and sisters Jan, Christine, and Sara, Ken grew up in Mattoon, Illinois.

In 1972, Ken received the degree Bachelor of Arts from Knox College in Galesburg, Illinois, where he majored in history. The University of South Florida awarded Ken the Master of Education degree in administration and supervision in 1977. He began his doctoral studies in mathematics education under the direction of Dr. Elroy Bolduc at the University of Florida in 1979.

Ken began his career in education as a houseparent at Chaddock Boys' School in Quincy, Illinois. After moving to Sarasota, Florida, he taught seventh grade mathematics for five years and was Director of Christian Education at the First United Methodist Church.

While completing his doctoral studies at the University of Florida, Ken taught elementary science methods and elementary mathematics methods in the Childhood Education Program. He was a College Coordinator for secondary

mathematics interns for five quarters. Ken taught Basic Mathematics for the Social Sciences in the Mathematics Department for one quarter.

Ken is a member of the National Council of the Teachers of Mathematics, the Florida Council of the Teachers of Mathematics, the Florida Education Association, and the Florida Educational Research Association.

Ken's wife, Mary E. (Walden) Henderson, completed her doctoral studies in English language arts education at the University of Florida and is the Director of Language Arts/Reading of the Duval County Public Schools, Jacksonville, Florida.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Elroy J. Bolduc, Jr.

Elroy J. Bolduc, Jr., Chairperson
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Teacher Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Associate Professor of Mathematics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the Division of Curriculum and Instruction in the College of Education and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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